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BOX PATENT APPLICATION
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TRANSMITTAL SHEET FOR PATENT APPLICATION

Dear Sirs:

Transmitted herewith for filing under 35 U.S.C. §111(a) is a written application for a patent.

Express Mail No.: EL493656490US

Title: Method for Alignment of Liquid Crystals Using Irradiated Liquid Crystal Films

Inventors: Yuri Reznikov, John West, Oleg Yaroshchuk

Docket No. KSU-188

Enclosed is:

Transmittal Letter with Certificate of Mailing and Authorization to Charge Deposit Account (2 pages - in duplicate)
Utility Patent Application Transmittal Sheet (1 page)
Fee Transmittal Sheet (1 page - in duplicate)
Print EFS Bibliographic Data Sheet (2 pages)
Combined Declaration and Power of Attorney (3 pages - unexecuted)
Specification:

12	pages of Description
3	pages of Claims
1	page of Abstract
4	pages of Drawings

Small Entity Statement
Information Disclosure Statement (2 pages)
Form PTO/SB/08A (1 page)
Form PTO/SB/08B (1 page)
Copies of Art Cited (6 references)
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Respectfully submitted,

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9-7-00
Date

9-8-00

A

JC921 U.S. PTO 09/07/00

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PTO/SB/05 (4/98)
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No.	KSU-188
First Inventor or Application Identifier	Yuriy Reznikov
Title	Method for Alignment of Liquid Crystals Using Irradiated Liquid Crystal Films
Express Mail Label No.	EL493656490US

JC893 U.S. PTO 09/656142 09/07/00

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
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1. [X] * Fee Transmittal Form (e.g., PTO/SB/17) (Submit an original and a duplicate for fee processing)
2. [X] Specification [Total Pages 16] (preferred arrangement set forth below)
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [X] Drawing(s) (35 U.S.C. 113) [Total Sheets 4]
4. Oath or Declaration [Total Pages 3]
   a. [X] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 C.F.R. § 1.63(d)) (for continuation/divisional with Box 16 completed)
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

NOTE FOR ITEMS 1 & 13 IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

5. [ ] Microfiche Computer Program (Appendix)
6. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
   a. [ ] Computer Readable Copy
   b. [ ] Paper Copy (identical to computer copy)
   c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. [ ] Assignment Papers (cover sheet & document(s))
8. [ ] 37 C.F.R.§3.73(b) Statement (when there is an assignee) [ ] Power of Attorney
9. [ ] English Translation Document (if applicable)
10. [X] Information Disclosure Statement (IDS)/PTO-1449 [X] Copies of IDS Citations
11. [ ] Preliminary Amendment
12. [X] Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
13. [X] * Small Entity Statement(s) (PTO/SB/09-12) [ ] Statement filed in prior application Status still proper and desired
14. [ ] Certified Copy of Priority Document(s) (if foreign priority is claimed)
15. [X] Other: Check $381

16. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in a preliminary amendment:

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: ______/______

Prior application information: Examiner ______ Group / Art Unit: ______

For CONTINUATION or DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 4b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

17. CORRESPONDENCE ADDRESS

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Name (Print/Type)	Michael F. Morgan	Registration No. (Attorney/Agent)	42,906
Signature	Michael F. Morgan	Date	9-7-00

FEE TRANSMITTAL for FY 2000

Patent fees are subject to annual revision.
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TOTAL AMOUNT OF PAYMENT ($)381.00

Complete if Known	
Application Number	New Application
Filing Date	
First Named Inventor	Yuriy Reznikov
Examiner Name	
Group / Art Unit	
Attorney Docket No.	KSU-188

METHOD OF PAYMENT (check one)

1. [X] The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	690	201	345	Utility filing fee	345.00
106	310	206	155	Design filing fee	
107	480	207	240	Plant filing fee	
108	690	208	345	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 345.00

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims	24	-20** =	4	X	9	=	36
Independent Claims	3	- 3** =	0	X	39	=	0
Multiple Dependent						=	0

**or number previously paid, if greater; For Reissues, see below

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	78	202	39	Independent claims in excess of 3
104	260	204	130	Multiple dependent claim, if not paid
109	78	209	39	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 36.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	0.00
127	50	227	25	Surcharge - late provisional filing fee or cover sheet.	0.00
139	130	139	130	Non-English specification	0.00
147	2,520	147	2,520	For filing a request for reexamination	0.00
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	0.00
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	0.00
115	110	215	55	Extension for reply within first month	0.00
116	380	216	190	Extension for reply within second month	0.00
117	870	217	435	Extension for reply within third month	0.00
118	1,360	218	680	Extension for reply within fourth month	0.00
128	1,850	228	925	Extension for reply within fifth month	0.00
119	300	219	150	Notice of Appeal	0.00
120	300	220	150	Filing a brief in support of an appeal	0.00
121	260	221	130	Request for oral hearing	0.00
138	1,510	138	1,510	Petition to institute a public use proceeding	0.00
140	110	240	55	Petition to revive - unavoidable	0.00
141	1,210	241	605	Petition to revive - unintentional	0.00
142	1,210	242	605	Utility issue fee (or reissue)	0.00
143	430	243	215	Design issue fee	0.00
144	580	244	290	Plant issue fee	0.00
122	130	122	130	Petitions to the Commissioner	0.00
123	50	123	50	Petitions related to provisional applications	0.00
126	240	126	240	Submission of Information Disclosure Stmt	0.00
581	40	581	40	Recording each patent assignment per property (times number of properties)	0.00
146	690	246	345	Filing a submission after final rejection (37 CFR § 1.129(a))	0.00
149	690	249	345	For each additional invention to be examined (37 CFR § 1.129(b))	0.00
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SUBTOTAL (3) ($) 0.00

SUBMITTED BY				Complete *(if applicable)*	
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Signature	Michael Morgan			Date	9-7-00

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STATEMENT CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) & 1.27(d))—NONPROFIT ORGANIZATION	Docket Number (Optional) KSU-188

Applicant, ~~Patentee, or Identifier~~: Yuriy Reznikov, et al.
Application ~~or Patent~~ No.: ______
Filed ~~or Issued~~: ______
Title: Method of Alignment of Liquid Crystals Using Irradiated Liquid Crystal Films

I hereby state that I am an official empowered to act on behalf of the nonprofit organization identified below:
NAME OF NONPROFIT ORGANIZATION Kent State University
ADDRESS OF NONPROFIT ORGANIZATION East Main and Lincoln Streets, Kent, OH 44242

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I hereby state that the nonprofit organization identified above qualifies as a nonprofit organization as defined in 37 CFR 1.9(e) for purposes of paying reduced fees to the United States Patent and Trademark Office regarding the invention described in:

- [ ] the specification filed herewith with title as listed above.
- [X] the application identified above.
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TITLE IN ORGANIZATION OF PERSON SIGNING Vice Provost and Dean of Research & Graduate Studies
ADDRESS OF PERSON SIGNING East Main and Lincoln Streets Kent, OH 44242
SIGNATURE [signature] DATE 9/7/00

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Fax One:: 330/376-9646

APPLICATION INFORMATION

Title Line One:: Method for Alignment of Liquid Crystals

Title Line Two:: Using Irradiated Liquid Crystal Films
Total Drawing Sheets:: 4
Formal Drawings?:: Yes
Application Type:: Utility
Docket Number:: KSU-188
Secrecy Order in Parent Appl.?:: No

REPRESENTATIVE INFORMATION

Registration Number One:: 26519
Registration Number Two:: 28837
Registration Number Three:: 36010
Registration Number Four:: 22325
Registration Number Five:: 22353
Registration Number Six:: 24726
Registration Number Seven:: 27182
Registration Number Eight:: 29096
Registration Number Nine:: 37400
Registration Number Ten:: 40139
Registration Number Eleven:: 42859
Registration Number Twelve:: 42906
Registration Number Thirteen:: 43921
Registration Number Fourteen:: 42451
Registration Number Fifteen:: 46069

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ALIGNMENT OF LIQUID CRYSTALS USING IRRADIATED LIQUID CRYSTAL FILMS

GOVERNMENT RIGHTS IN THE INVENTION

The United States government has a paid-up license in this invention and may have the right in limited circumstances to require the patent owner to license others on reasonable terms as provided for by the terms of Grant DMR89-20147, awarded by the National Science Foundation.

FIELD OF THE INVENTION

The present invention is directed to alignment of liquid crystals using an alignment layer. More particularly, the invention is directed to alignment layers of irradiated liquid crystal films.

BACKGROUND OF THE INVENTION

Liquid crystals consist of anisotropic molecules. The average direction of the long molecular axis is called the director, $\boldsymbol{d}$. The director orientation is determined by the anchoring of the liquid crystal on rigid substrates and is characterized by the direction of the axis of easy director orientation, $\boldsymbol{e}$, and anchoring energy W.

Reorientation of the director caused by the application of an external electric field is the basis of operation of liquid crystal displays. The basic unit of liquid crystal devices is a liquid crystal cell, which includes two rigid substrates with a liquid crystal sandwiched between. To obtain uniform brightness and high contrast ratio it is desired to produce a uniform alignment of liquid crystals in the cell.

To produce uniform planar orientation of liquid crystals, several techniques involving different polymer materials are generally used.

One technique is the rubbing method. Polymer layers are deposited on the substrate and rubbed unidirectionally. The director, ***d***, is usually aligned parallel to the direction of rubbing in the plane of the substrate. A pretilt angle, φ, between the substrate and the director in the plane perpendicular to the substrate may be produced by this method.

The rubbing method produces stable planar alignment with strong anchoring. However, this technique has some drawbacks. In particular, dust and static electricity generated during the rubbing can cause defects in liquid crystal displays. Moreover, it is difficult to orient selected regions of the liquid crystal surface locally so that each region has a different orientation. It is difficult to obtain multi-domain alignment.

Another technique is the photo aligning method. Photosensitive polymer layers are deposited on the substrate and are irradiated by polarized UV light. Such layers possesses a light induced anisotropy axis that produces high quality planar alignment of the liquid crystal molecules in a preferred axial direction perpendicular or parallel to the polarization vector of the UV light beam, ***E***. Tilted alignment can be obtained by oblique irradiation of the polymer layer.

The photo aligning method produces stable planar and tilted alignment of most commercial nematic liquid crystals. In contrast to rubbing, no electrostatic charges or dust are produced on the aligning surface. Also, the direction of the easy axis and the anchoring energy can be locally varied by changing the direction of light polarization and the time of UV exposure.

An example of the photo aligning method can be found in U.S. Patent 5,389,698 to V.Chigrinov et al, which uses a photopolymer polyvinyl-cinnamate

aligning layer irradiated with plane-polarized light. Another example of the photo aligning method can be found in U.S. Patent No. 5,807,498 to Gibbons et al, which uses polyimides with di-aryl ketones and di-aryl ketones alignment layers.

Both of the above methods use special polymer materials to produce the alignment of the liquid crystals.

Another method uses light irradiation of a liquid crystal cell filled with dye-doped liquid crystals. This method can produce planar alignment of liquid crystals (Jap.Journ.Appl.Phys. v.34 (1995) 566). The mechanism of the alignment is postulated to be a result of absorption of the light by the dye molecules followed by their anisotropic adsorption onto the substrate. This method, however, requires the use of dye-doped liquid crystals to form an alignment layer.

United States Patent No. 5,032,009 to Gibbons et al. discloses exposing anisotropically absorbing molecules that are on a substrate, disposed in a liquid crystal medium, and the liquid crystals themselves to linearly polarized light. However, non-mesogenic molecules, such as a polyimide, are coated onto the substrate and exposed to linearly polarized light to produce alignment.

What is needed in the art is an alignment layer that can be formed from light irradiated liquid crystals.

It is therefore an object of the invention to provide a method of forming an alignment layer made from a liquid crystal film that is irradiated with light.

It is another object of the invention to provide a method of forming a liquid crystal cell that has at least one alignment layer made from a liquid crystal film that is irradiated with light.

SUMMARY OF THE INVENTION

The present invention provides a method for forming a liquid crystal alignment layer comprising: disposing liquid crystals in a solvent; depositing the liquid crystals and solvent on a substrate; removing the solvent to form a liquid crystal film; and irradiating the liquid crystal film with light wherein the wavelength of the light overlaps the absorption spectrum of the liquid crystal.

Also provided is a method of forming a liquid crystal cell comprising: providing two opposed substrates each covered with an electrode; disposing liquid crystals in a solvent; depositing the liquid crystals and solvent on at least one of the electrode covered substrates on the surface facing the other substrate; removing the solvent to form a liquid crystal film; irradiating the liquid crystal film with light wherein the wavelength of the light overlaps the absorption spectrum of the liquid crystal; placing spacers between the substrates; sealing three of the sides of the substrate to form a cell; filling the cell with a second liquid crystal; and sealing the cell.

Also provided is a liquid crystal display comprising a first and second cell wall structure, electrodes disposed on facing sides of said first and second cell wall structures, an alignment layer disposed on at least one of said electrodes, and first liquid crystals disposed within a space between the first and second cell wall structures, wherein the alignment layer comprises a liquid crystal film comprising second liquid crystals, wherein the liquid crystal film has been irradiated with light that overlaps the absorption spectrum of the second liquid crystals.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is graph of the irradiance of a xenon lamp.

Figure 2 is a graph of the absorption of the film of a liquid crystal mixture ZLI-4792 from Merck deposited on a substrate.

Figure 3 is a photomicrograph that shows the alignment in a liquid crystal cell that was prepared in Example 1.

Figure 4 is a schematic of a liquid crystal cell.

DETAILED DESCRIPTION OF THE INVENTION

A method is provided for forming a liquid crystal alignment layer. The method includes the steps of: disposing liquid crystals in a solvent; depositing the liquid crystals and solvent on a substrate; removing the solvent to form a liquid crystal film; and irradiating the liquid crystal film with light wherein the wavelength of the light overlaps the absorption spectrum of the liquid crystal.

The liquid crystal that can be used to form the liquid crystal layer can be any liquid crystal with molecules that have dichroic absorption matched to the irradiating wavelength and which undergo a photochemical transformation. Examples of photochemical transformation include, but are not limited to, cis-trans photoisomerization, photo-induced absorption or desorption, or photochemical reaction.

Generally, wavelengths of light in the UV region of the spectrum are used because liquid crystal molecules generally absorb light in the UV wavelengths.

Suitable examples of the liquid crystal include, but are not limited to, 4-cyano-4'-alkylbiphenyls, 4-cyano-4'-alkyloxybiphenyls, 4-alkyl-4'alkoxy-azoxybenzenes. Specific examples of compounds within these families are 4-cyano-4'-pentylbiphenyl, 4-cyano-4'-hexyloxibiphenyl and 4-butyl-4'metoxy-azoxybenzene.

Commercial mixtures containing all the above can be also used. Illustrative are the mixture E7 from BDH, Ltd, UK and the mixture ZLI 4792 from Merk, USA.

The liquid crystal alignment layer ranges from about a thickness that corresponds to the monolayer of LC molecules on substrate), which is about 2nm, to about 0.1 μm in thickness. Preferably, the liquid crystal alignment layer ranges from about 2nm to about 20nm in thickness.

The irradiating light of the present invention must contain a linearly polarized component, i.e. must be either linearly polarized or elliptically polarized, or partially polarized. Most preferably, the irradiating is providing by linearly polarized light. The irradiating light must have a wavelength in the absorption band of the aligning liquid crystal layer. Typically, the light will be in the ultraviolet range as the liquid crystal compounds have peak absorbtion in this range. Preferably, the light will have a wavelength within the range of about 200 to about 350 nm. The most preferred source of light is Hg- or Xe-lamps.

The direction of the easy axis is given by the polarization of the irradiating light (in most cases the easy axis is perpendicular to the polarization of the irradiating light). Therefore, the direction of the easy axis can be locally varied across the alignment layer by changing the direction of light polarization in the range 0 – 360°. The value of the anchoring energy is given by the irradiating intensity and exposure. Therefore, the anchoring energy can be locally varied across the alignment layer by changing the direction of light polarization and the time of the exposure. The typical range of the variety of the anchoring energy is about 10^{-4} – 10^{-2} erg/cm^2. Exposure times and light intensities vary widely with the materials and light source used and can range from about tens of seconds to about several hours.

Prior to irradiating, a mask may be placed over the liquid crystal film. The mask is removed after the film is irradiated. The mask can be any desired shape to provide a pattern to the liquid crystal film.

The liquid crystal film can be deposited on the substrate by any method. Suitable examples of depositing the film are spin coating and dip coating. For spin coating, the liquid crystal is dissolved in a solvent. The solvent can be any solvent that will dissolve the liquid crystal. Suitable examples of the solvent include, but are not limited to, aliphatic hydrocarbons (such as, hexane, octane, cyclohexane) aromatic hydrocarbons (such as, benzene, toluene, chlorobenzene), ethers (such as, ethylene glycol dimethylether, 1,4-dioxane, tetrahydrofuran), esters (such as, ethyl acetate, butyl acetate, diethyl carbonate,) ketones (such as, acetone, cyclohexanone, 2-butanone), and alcohols (such as, 2-propanol, ethanol, methanol). The solvent can be removed by any method, including evaporation at room temperature or with applied heat.

The substrate can be any material commonly used for fabricating liquid crystal cells. Materials such as glass, quartz or plastic can be used. The substrate materials can also be any materials commonly used for fabricating chips, for example silicon.

The liquid crystal alignment layer can then be incorporated into a liquid crystal cell. A liquid crystal cell typically comprises opposed substrates, electrodes on the substrates, alignment layers disposed over the electrodes, spacers between the substrates to control the thickness of the liquid crystal cell, and liquid crystals disposed between the substrates. Figure 4 is a schematic of a typical liquid crystal cell. Layers 11 and 15 represent the combined substrate and electrodes. Layers 12 and 14 represent the alignment layers. Layer 13 represents the liquid crystal material. And, layer 16 is a voltage source to power the cell.

The liquid crystal alignment layer can be placed on one or both of the substrates in the liquid crystal cell. When the liquid crystal alignment layer is placed on only one of the substrates, any known alignment material may be placed on the remaining substrate. Other alignment materials include, but are not limited to, rubbed or light-irradiated polyimides, rubbed polyvinyl-alcohol, light-irradiated polyvinyl-cinnamate, light-irradiated polysiloxane-cinnamates, oblique evaporated Al_2O_3.

The electrodes of the liquid crystal cell can be fabricated from any material known to be used for electrodes for liquid crystal cells. Suitable materials for the electrodes include, but are not limited to, indium-tin-oxide (ITO), stannic oxide SnO_2, aluminum, chromium, silver, or gold.

Additional information relating to the invention can be found in "Photoalignment of Liquid Crystals by Liquid Crystals" by Reznikov et al., Physical Review Letters, Volume 84, Number 9, 28 February 2000, pages 1930-1933, which is incorporated herein by reference.

SPECIFIC EMBODIMENTS OF THE INVENTION

Example 1

The liquid crystal mixture ZLI 4792, from Merck, was dissolved in hexane at a weight concentration of 0.5%. A droplet of this solution was deposited on a rectangular glass substrate and spin-coated for 20 seconds at 3000 rpm. Then the substrate was warmed to 50°C on a hot stage and maintained for 30 minutes. A uniform liquid crystal film with a thickness of less than 1 μm was produced on the substrate.

A portion of the liquid crystal film was irradiated with polarized UV light from a Xe-lamp. The irradiation spectrum of the lamp (Figure 1) overlaps the absorption spectrum of the liquid crystal film (Figure 2). The spectrum of the liquid

crystal deposited on the substrate is different from the spectrum of the bulk liquid crystal because of the interaction between the liquid crystal and the substrate. The film was exposed for 20 minutes at an intensity of 5 mW/cm^2. The polarization of the UV-light, E, was parallel to the long side of the glass substrate.

The glass substrate from above and another glass substrate with a rubbed layer of polyimide, NISSAN 7792 from Nisssan, were used to form a liquid crystal cell. The direction of rubbing on the substrate covered with the polyimide was parallel to the long side of the substrate. The substrates were separated by rigid 20μm spacers. The resulting cell was warmed to 100°C and filled with the liquid crystal ZLI 4792.

The cell showed poor alignment with a quasi-planar liquid crystal texture in the non-irradiated area and a high quality twisted-planar alignment in the irradiated area (Figure 3). The director on the liquid crystal aligning layer aligned approximately perpendicular to the polarization of the irradiating UV light. Thermal treatment (130°C for 1 hour) did not change the liquid crystal alignment in the irradiated area.

Example 2

The same procedure as described in Example 1 was used except that the cell was filled with the liquid crystal 4-cyano-4'-pentylbiphenyl (K15) from Merck. The cell showed poor alignment with a quasi-planar liquid crystal texture in the non-irradiated area and a high quality weakly twisted planar alignment in the irradiated area. Thermal treatment (130°C for 1 hour) did not change the liquid crystal alignment in the irradiated area.

Example 3

The same procedure was used as described in Example 1 except that the liquid crystal that was spin coated on the glass substrate and used for alignment was K15, and the cell was filled with the liquid crystal K15. The cell showed poor

alignment with a quasi-planar liquid crystal texture in the non-irradiated area and a high quality homeotropic alignment in the irradiated area. Thermal treatment (130°C for 1 hour) did not change the liquid crystal alignment in the irradiated area.

Example 4

The same procedure as described in Example 3 was used but the K15 film was produced as described below.

The liquid crystal K15 was dissolved in isopropyl alcohol at a weight concentration of 0.2%. A chemically clean rectangular quartz substrate was put in this solution and maintained for 45 minutes. The substrate was taken out of the solution, washed in isopropyl alcohol for 20 seconds, and dried by a nitrogen gas stream to remove the solvent. As a result, a uniform liquid crystal film with a thickness comparable the thickness of the K15 monolayer was produced on the substrate.

The cell showed poor alignment with a quasi-planar liquid crystal texture in the non-irradiated area and a good quality twisted-planar alignment in the irradiated area. The director on the liquid crystal aligning layer was aligned 30° to the direction of rubbing on the surface covered with rubbed polyimide layer.

Example 5

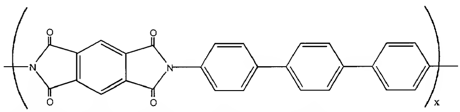
The same procedure as described in Example 1 was used except the glass substrates were covered with the liquid crystal K15 and the cell was filled with the liquid crystal ZLI-4792. The cell showed poor alignment with a quasi-planar liquid crystal texture in the non-irradiated area and a high quality twisted planar alignment in the irradiated area. The director on the LC aligning layer aligned parallel to the rubbing direction of polyimide surface. Thermal treatment (130°C for 1 hour) did not change the liquid crystal alignment in the irradiated area.

Example 6

The same procedure as described in Example 1 was used except the glass substrates were covered with the liquid crystal K15 and the cell was filled with the liquid crystal 4-butyl-4'metoxy-azoxybenzene (from Niopic, Russia). The cell showed poor alignment with a quasi-planar liquid crystal texture in the non-irradiated area and a high quality twisted planar alignment in the irradiated area. The director on the liquid crystal aligning layer aligned parallel to the rubbing direction of polyimide surface. Thermal treatment (130°C for 1 hour) did not change the liquid crystal alignment in the irradiated area.

Example 7

The same procedure as described in Example 1 was used except the liquid crystal K15 was deposited on a layer of a non-photosensitive polyimide, given by the following structure:



wherein x is a number from about 15,000 to about 70,000.

The cell was filled with the liquid crystal K15. The cell showed poor alignment with a quasi-planar liquid crystal texture in the non-irradiated area and a high quality twisted-planar alignment in the irradiated area. The director on the liquid crystal aligning layer aligned approximately perpendicular to the polarization of the irradiating UV light. Thermal treatment (130°C for 1 hour) did not change the liquid crystal alignment in the irradiated area.

Example 8

The same procedure as described in Example 1 was used except that the liquid crystal K15 was deposited on a layer of a non-photosensitive polyimide, see Example 7, and the cell was filled with the liquid crystal ZLI 4792. The cell

showed poor alignment with a quasi-planar liquid crystal texture in the non-irradiated area and a high quality twisted-planar alignment in the irradiated area. The director on the liquid crystal aligning layer aligned approximately perpendicular to the polarization of the irradiating UV light. Thermal treatment (130°C for 1 hour) did not change the liquid crystal alignment in the irradiated area.

Example 9

The same procedure as described in Example 1 was used except that the liquid crystal K15 was deposited on a transparent conductive layer of indium tin oxide (ITO) and the cell was filled with the liquid crystal ZLI 4792. The cell showed a poor quasi-planar liquid crystal texture in the non-irradiated area and a high quality planar-twisted alignment in the irradiated area. The director on the liquid crystal aligning layer aligned approximately perpendicular to the polarization of the irradiating UV light. Thermal treatment (130°C, 1 hour) did not change the liquid crystal alignment in the irradiated area.

It should be appreciated that the present invention is not limited to the specific embodiments described above, but includes variations, modifications and equivalent embodiments defined by the following claims.

CLAIMS

What is claimed is:

1. A method for forming a liquid crystal alignment layer comprising:
   a. disposing liquid crystals in a solvent;
   b. depositing the liquid crystals and solvent on a substrate;
   c. removing the solvent to form a liquid crystal film; and
   d. irradiating the liquid crystal film with light wherein the wavelength of the light overlaps the absorption spectrum of the liquid crystal.

2. The method of claim 1, wherein the depositing is one of spin coating and dip coating.

3. The method of claim 1, wherein the light is one of linearly polarized, elliptically polarized, or partially polarized.

4. The method of claim 1, wherein the liquid crystal film has a thickness ranging from about 2nm to about 0.1 μm.

5. The method of claim 1, wherein the liquid crystal film has a thickness ranging from about 2nm to about 20 μm.

6. The method of claim 1 further comprising laying a patterned mask over the liquid crystal film prior to the irradiating step and removing the mask after the irradiating step.

7. The method of claim 1, wherein the liquid crystal is selected from the group consisting of 4-cyano-4'-alkylbiphenyls, 4-cyano-4'-alkyloxybiphenyls, 4-alkyl-4'alkoxy-azoxybenzenes and mixtures thereof.

8. The method of claim 1, wherein the liquid crystal film has an easy axis of orientation and an anchoring energy, wherein at least one of the easy axis of orientation and anchoring energy is locally varied across the liquid crystal film by at least one of exposure time of the light at a point on the liquid crystal film and polarization of the light at a point on the liquid crystal film.

9. The method of claim 8, wherein the direction of the easy axis can be locally varied across the alignment layer from 0° to 360°.

10. The method of claim 8, wherein the anchoring energy ranges from about 10^{-4} to about 10^{-2} erg/cm^2.

11. A method of forming a liquid crystal cell comprising:

a. providing two opposed substrates each covered with an electrode;
b. disposing first liquid crystals in a solvent;
c. depositing the first liquid crystals and solvent on at least one of the electrode covered substrates on the surface facing the other substrate;
d. removing the solvent to form a liquid crystal film;
e. irradiating the liquid crystal film with light wherein the wavelength of the light overlaps the absorption spectrum of the liquid crystal;
f. placing spacers between the substrates;
g. sealing three of the sides of the substrate to form a cell;
h. filling the cell with a second liquid crystal; and
i. sealing the cell.

12. The method of claim 11, wherein the depositing is one of spin coating and dip coating.

13. The method of claim 11, wherein the light is one of linearly polarized, elliptically polarized, or partially polarized.

14. The method of claim 11, wherein the liquid crystal film has a thickness ranging from about 2nm to about 0.1 μm.

15. The method of claim 11, wherein the liquid crystal film has a thickness ranging from about 2nm to about 20nm.

16. The method of claim 11 further comprising laying a patterned mask over the liquid crystal film prior to the irradiating step and removing the mask after the irradiating step.

17. The method of claim 11, wherein the second liquid crystal is the same as the first liquid crystal in the liquid crystal film.

18. The method of claim 11, wherein the first liquid crystal has an easy axis of orientation and an anchoring energy, wherein at least one of the easy axis of orientation and anchoring energy is locally varied across the liquid crystal film by at least one of exposure time of the light at a point on the liquid crystal film and polarization of the light at a point on the liquid crystal film.

19. The method of claim 11, wherein the first liquid crystal is selected from the group consisting of 4-cyano-4'-alkylbiphenyls, 4-cyano-4'-alkyloxybiphenyls, 4-alkyl-4'alkoxy-azoxybenzenes, and mixtures thereof.

20. The method of claim 18, wherein the direction of the easy axis can be locally varied across the alignment layer from 0° to 360°.

21. The method of claim 18, wherein the anchoring energy ranges from about 10^{-4} to about 10^{-2} erg/cm^2.

22. The method of claim 11, wherein an alignment layer is disposed on one of the substrates.

23. The method of claim 22, wherein the alignment layer is selected from the group consisting of rubbed polyimides, light-irradiated polyimides, rubbed polyvinyl-alcohol, light-irradiated polyvinyl-cinnamate, light-irradiated polysiloxane-cinnamates, and oblique evaporated Al_2O_3.

24. A liquid crystal display comprising a first and second cell wall structure, electrodes disposed on facing sides of said first and second cell wall structures, an alignment layer disposed on at least one of said electrodes, and first liquid crystals disposed within a space between the first and second cell wall structures, wherein the alignment layer comprises a liquid crystal film comprising second liquid crystals, wherein the liquid crystal film has been irradiated with light that overlaps the absorption spectrum of the second liquid crystals.

ABSTRACT OF THE INVENTION

A method is provided for forming an alignment layer for a liquid crystal cell that is made from a liquid crystal film that has been irradiated with light. The method includes the steps of disposing a liquid crystal film on a substrate and then irradiating the liquid crystal film with light. Also, a liquid crystal display that includes an alignment layer that is a liquid crystal film that has been irradiated with light.

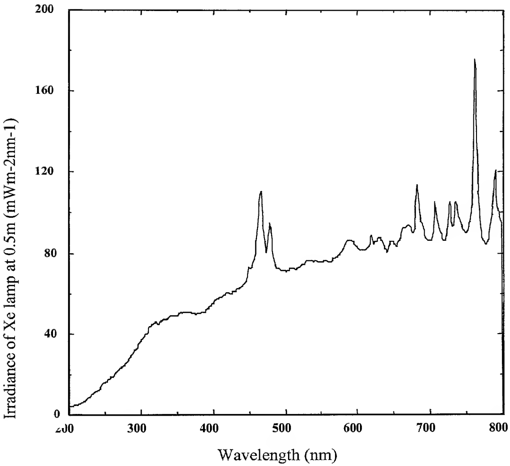

200
160
120
80
40
0
200
300
400
500
600
700
800
Irradiance of Xe lamp at 0.5m (mWm-2nm-1)
Wavelength (nm)

Figure 1

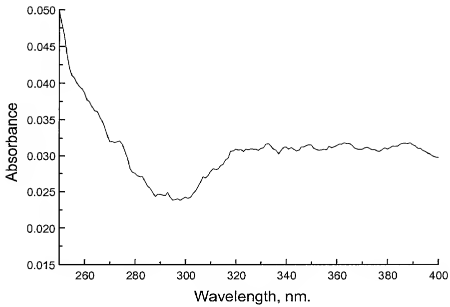

Absorbance
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
260
280
300
320
340
360
380
400
Wavelength, nm.

Figure 2

FIG.3

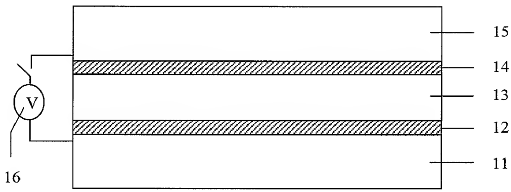


Figure 4

Docket Number KSU-188

Patent
Joint Inventors

DECLARATION AND POWER OF ATTORNEY

As below named inventors, we hereby declare that:

Our residence, post office address and citizenship are as stated below next to our names.

We believe we are the original, first and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Method for Alignment of Liquid Crystals Using Irradiated Liquid Crystal Films

including any amendments referred to below,
the specification of which

__X__ is attached hereto.
_____ was filed on __________ as Application Serial No. __________ and
was amended on __________

We hereby state that we have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

We hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Number	Country	Date Filed	Priority Claimed Yes	Priority Claimed No
None				

We hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

Provisional Application Number	Filing Date

We hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, we acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial Number	Filing Date	Status

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As named inventors, we hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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